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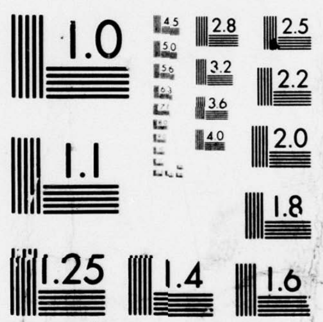

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NRL Memorandum Report 3830

Pharos II Alignment System

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Plasma Physics Division

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This memo report is a documentation of the manual alignment system on the Pharos II Nd Glass Laser System and describes the operation of this system in a step-by-step fashion.

Further improvements are possible and planned (including a fully automated system), hence, this is an interim report which reflects the status as of Mid-1977 rather than a final report. The alignment system achieves beam pointing to accuracies better than 40 μr and beam centering on components to less than 2% of the diameter. Temporal synchronization to 5 ps is also achieved.

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CONTENTS

PHAROS II ALIGNMENT SYSTEM

PRESENT PHAROS II CENTERING AND POINTING TECHNIQUES

The present manual technique used on the Pharos II laser system provides an illustration of the precision obtainable with relatively simple techniques. The results obtained with this technique include:

- angular alignment of both beams to within $\pm$ 40 μrad at full power,
- centering of all apertures in the laser system on the laser beam to better than $\pm$ 2%,
- alignment time for a "cold start" -- less than 15 minutes, and
- intershot alignment checks - less than 5 minutes.

If it is required at some future point it appears possible to improve this capability by a factor of $\sim$ 5 in both angular alignment and centering. This has not been done to date as the procedure would involve more steps and would not of itself result in greater accuracy as the present overall accuracy is limited by our ability to position targets to better than $\pm$ 5 μm (= 50 μr) in the target plane. For the present two beam target studies this appears adequate for typical 50 μm diameter or larger targets.

1. Pharos II description

The Pharos II laser system is shown in Fig. 1. From an alignment standpoint there are four sections to the laser; successive sections are decoupled by mirror pairs:

Note: Manuscript submitted July 21, 1978.

- the first section includes the mode-locked oscillator, pulse selector and Nd:Yag preamplifiers. In this section a mode-locked pulse train is generated, the largest pulse selected and then amplified to ~ 20 mJ in a 100 ps pulse. The components in this section may require day-to-day tweaking so this section is decoupled from the next segment by a mirror pair. The components in the oscillator section are mounted on granite benches. Alignment of the oscillator and preamplifiers is a complex procedure which has been treated elsewhere. In this document we will pick up the alignment procedure from the point where a pulse of adequate quality is being generated and is incident on the first mirror of the mirror pair.

- the second segment contains two rod amplifiers as well as optical isolators. At the end of this segment the pulse energy is approximately 300 mJ. The two rod amplifiers (ø 23 mm and ø 32 mm) are helical flashlamp amplifiers originally manufactured by CGE. The optical isolators; one Pockel's cell, one Faraday rotator, and one saturable absorber serve to suppress pre-pulses as well as to prevent laser damage caused by backreflected energy. This segment is decoupled from the following segment(s) by mirror pairs.

- The final two parallel segments consist of a rod amplifier (ø 45 mm) followed by two disc amplifiers and a Faraday rotator. In this segment the pulse is amplified up its final intensity, ~ 30 J/arm. From an alignment standpoint this segment extends to the focusing optics so its total length is ~ 36 meters.

2. Pharos II Alignment Procedure

The procedure we have evolved for aligning Pharos II manually uses centering detectors and reference points. The detectors used are Hammamatsu - IR vidicons.

First Alignment Point

The first alignment point is at the input to the second section. The first mirror of the mirror pair is used to center the beam in a 5 mm reference aperture immediately following the second mirror of the pair (cf. Fig. 2). Several techniques are possible for aligning the 1st mirror so that the beam centers on the aperture; all routinely give alignment to better than ± 5% of the aperture.

- The pulses from the oscillator section are strong enough to burn Polaroid (TM) film at this location; centering can be checked directly at the aperture and downstream from it as the pattern develops.

- An IR vidicon can be used to monitor the pattern after the aperture. Manually this gives equivalent precision, but with more sophiscated processing centering to very high precisions (approaching ~ ± .1% of the aperture) has been demonstrated in the laboratory.

The second approach has the advantage that the vidicon monitor can be located adjacent to the gimbal controls for mirror No. 1 for operator ease, while the first approach requires iteration or two operators, or a motorized gimbal mount for mirror No. 1.

A "flaw" in either procedure at the present is that the aperture is not located coincident to the alignment point on the surface of mirror No. 2 so angular errors in mirror No. 2 will give a centering

error. This error is quite small compared to the necessary precision at the present time, i.e. < 0.5% of the aperture diameter, so this effect has not been corrected.

Second Alignment Point

Once proper centering has been achieved on the second mirror the next step is to achieve proper centering on the output of the intermediate amplifier section, i.e., on the splitting optics.

The initial layout is shown in Fig. 3. With the beam aligned on mirror No. 2 and the aperture used in the preceding step removed, the oscillator pulse is allowed to propagate up the optical bench.

The diverging lens has been placed its own focal length away from mirror No. 2. Beyond the lens the oscillator pulse will appear to be a spherical wave emanating from the correct point on mirror No. 2 whether or not the No. 2 mirror is correctly aligned in angle.

A secondary aperture placed on a kinematic mount near the turning mirrors can then be used to define the correct optical axis. When the oscillator is fired the Fresnel pattern of this second aperture will define the correct beam position on the vidicon. By then removing the second aperture and reinserting the aperture near mirror No. 2 the actual propagation direction can be defined.

Mirror No. 2 is then adjusted in angle to center the pattern on the reference pattern. This procedure manually appears to be accurate to ± 200-300 μm. With computer control and processing greater accuracy should be possible (i.e., ~ 20-30 μm).

Third (and Fourth) Alignment Points

These alignment points are in the target room and are 30 meters from the turning mirrors. The two are identical operations (one per beam) so we will describe only one of them.

We are assuming that there is negligible long term sag in the turning optics in term of centering on the turning mirror because of the short path (i.e., 60 cm) and that the chief problem is angular drifts between mirror and target ($\sim$ 30 m).

Figure 4 shows the set up in the target room for centering the beams. The removable aperture (2 mm) is the reference point in the target room.

First the auxiliary mirror and the aperture are placed on the optical rail. The oscillator is then pulsed to get a reference point on the vidicon screen. Next the reference aperture is removed and the alignment aperture before mirror No. 3 put in. The oscillator is pulsed again and gimbal No. 3 adjusted as needed to center the oscillator properly on the vidicon.

Various tests and cross checks would indicate a 30-40 μrad pointing accuracy is attained via this procedure.

3. Occasional Alignment and Set-up Procedures

In this section several aspects of the alignment of Pharos II are treated which are not necessary from day to day but which are required for initial set up and after natural or man-made catastrophies.

Component Centering

It is necessary both for maximum beam symmetry and power to have the laser beam well centered in the aperture of the rod amplifiers. There is another reason which is as important for pellet experiments; the amplifiers when optically pumped act as long focal length lenses. If the oscillator beam is not centered in the amplifiers, the high power beam in addition to focal zoom due to dynamic lensing may also be deflected to the side.

The vidicon alignment system can be used to give good amplifier centering to $< \pm 2\%$ of the amplifier diameter as presently used. With a minor modification to the procedure, centering to $\pm \frac{1}{2}\%$ could be attained but dynamic tests do not warrant this at present; i.e., no dynamic deflection is detectable with $\pm 2\%$ centering. The procedure we have evolved entails using "caps" with 2 mm diameter holes centered on the ends of the rods and viewing the center of this pattern relative to the pattern with the standard aperture, on the kinematic mount after the ϕ 32 amplifier.

As noted before the negative lens gives an apparent spherical wave emanating from a point on mirror 2 and the standard alignment aperture on its kinematic mount defines the desired optical axis. If a cap with a centered hole is placed on a rod end it defines the optical axis of the rod. By use of the target room viewing system , any difference can be noted and corrected by the appropriate translations of the laser rod. The spherical wave is collimated by the positive lens in front of the

disc amplifier, so displacements after that point show up in the target room at unit magnification.

For earlier stages there is magnification of the offset. The apparent displacement Δ_2 is related to the real displacement Δ_1, by

$$\frac{\Delta_2}{\Delta_1} = \frac{f}{x}$$

where f = 11 meters and x is the distance from mirror No. 2 to the test piece.

If we assume a resolution of $\pm$ 1 mm at the target end, which is not particularly precise we can estimate the centering accuracy for the amplifiers;

<u>23 mm</u> $\Delta_1 = \pm 1.0 \text{ mm} \times (\frac{3}{11}) = \pm 3 \text{ mm}$
($\pm$ 1.5%)

<u>32 mm</u> $\Delta_1 = \pm .55 \text{ mm}$
($\pm$ 1.7%)

<u>45 mm</u> $\Delta_1 = \pm .8 \text{ mm}$
($\pm$ 1.75%)

<u>Discs</u> $\Delta_1 = \pm 1 \text{ mm}$
($\pm$ 1.5%)

If the collimating lens is removed these centering accuracies will improve by a factor of four, because of the longer lever arm ($f \rightarrow 44$ meters).

Synchronization

Pharos II was designed to be essentially synchronized by the layout; therefore, no large adjustment is built into the system. Minor adjustment (± 200 ps) can be effected at the beam splitter optics. Figure 5 shows a schematic of the optical elements involved in the synchronization.

The beam splitter is a polarizer; hence, its angular adjustment is not optional. It is placed to give 50% reflection of the incident beam. Mirrors No. 3 through No. 7 give nominal 99% reflection for 45° incidence. They can be offset by up to ± 5° from 45° incidence without seriously affecting the reflectance. The path adjustment is done by adjusting mirror No. 5 in angle.

The actual time of arrival at the target is checked by placing a gold-plated prism at the focus position in the target chamber. This deflects both beams by 90° through another f/2 lens which recollimates them. By adjustment of the position (Z-axis) of the f/2 lens the beams can be made to focus on the slit of the EPL streak camera. Streaking the master oscillator then will show two effects simultaneously:

- lack of synchronization of the beams will be indicated by a temporal offset
- prism and focus lens positioning will be indicated by the spot sizes of the two beams on the slit of the EPL.

Synchronization with the EPL

The EPL is capable of 4-5 ps time resolution, but only on the two

fastest streak speeds. For slower streak speeds the dynamic resolution of 5 lp/mm dominates. For ease of performing this measurement with the best resolution it is important that the camera have a relatively new Krytron trigger tube. If the trigger pulse (from an ITT coaxial photodiode) is 20-50 volts and the Kryton is a good one, the triggering standard deviation should be < 100 ps.+

If the triggering reliability is poor; first check trigger pulse amplitude on a scope such as a Tektronix 519; if the amplitude (before the T50/T125 matching pad) corresponds to 20 to 50 V on 50 Ω cable and the laser stability is good; then the Krytron must be replaced even if it is brand new.

If the pulse amplitude is low or the reliability is poor either the laser oscillator or the photodiode alignment is incorrect. These should be fixed before proceeding.

Once the EPL camera is working, synchronization can be determined. If it is off, the following procedure should be followed:

1. Slew mirror No. 5 in the horizontal plane to give the indicated correction.

2. Move mirror No. 4 to the appropriate position to recenter the beam on it. Check with the alignment aperture before the splitter for angular error and adjust pointing gimbals on No. 4 mirror to give correct placement using target area vidicon system. Then place cap on input

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+ do not exceed 100 V under any circumstances.

end of 45 mm rod to check for centering. If it is not centered (and it probably will not be), mirror No. 4 should be translated towards (or away from) mirror No. 5 to give good apparent centering. The alignment stop should be replaced and the pointing checked.

Reiterate this procedure (translating No. 4 mirror) until both stops show good centering. (Movement of 45 mm amplifier will introduce angular error at the target).

3. Check synchronization with the EPL camera and reiterate steps 1 and 2 if necessary.

Once synchronized the beams should stay synchronized adequately. In routine operation day to day shifts of < 3 ps can be expected if the rest of the alignment is followed because of the reasonably precise centering adjustments.

Acknowledgements

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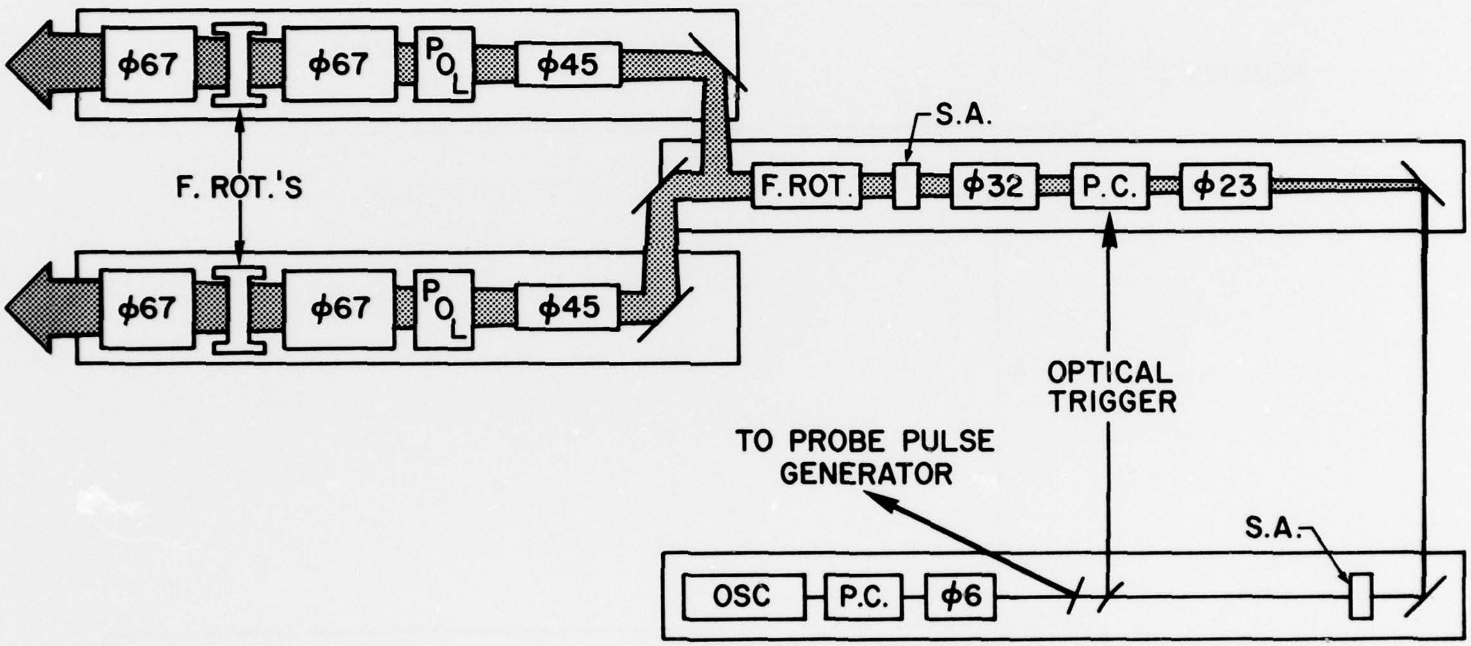

Fig. 1 - Pharos II Schematic. The oscillator-preamplifier section generates a pulse of nominal energy 20 mJ in 100 ps. This is amplified to 0.5 Jould in the intermediate amplifier section and then split into two beams. The final amplification stages consist of a 45 mm diameter rod amplifier $(e^{\alpha l} \sim 30)$ and two 67 mm aperture disc amplifiers $(e^{\alpha l} \sim 10)$.

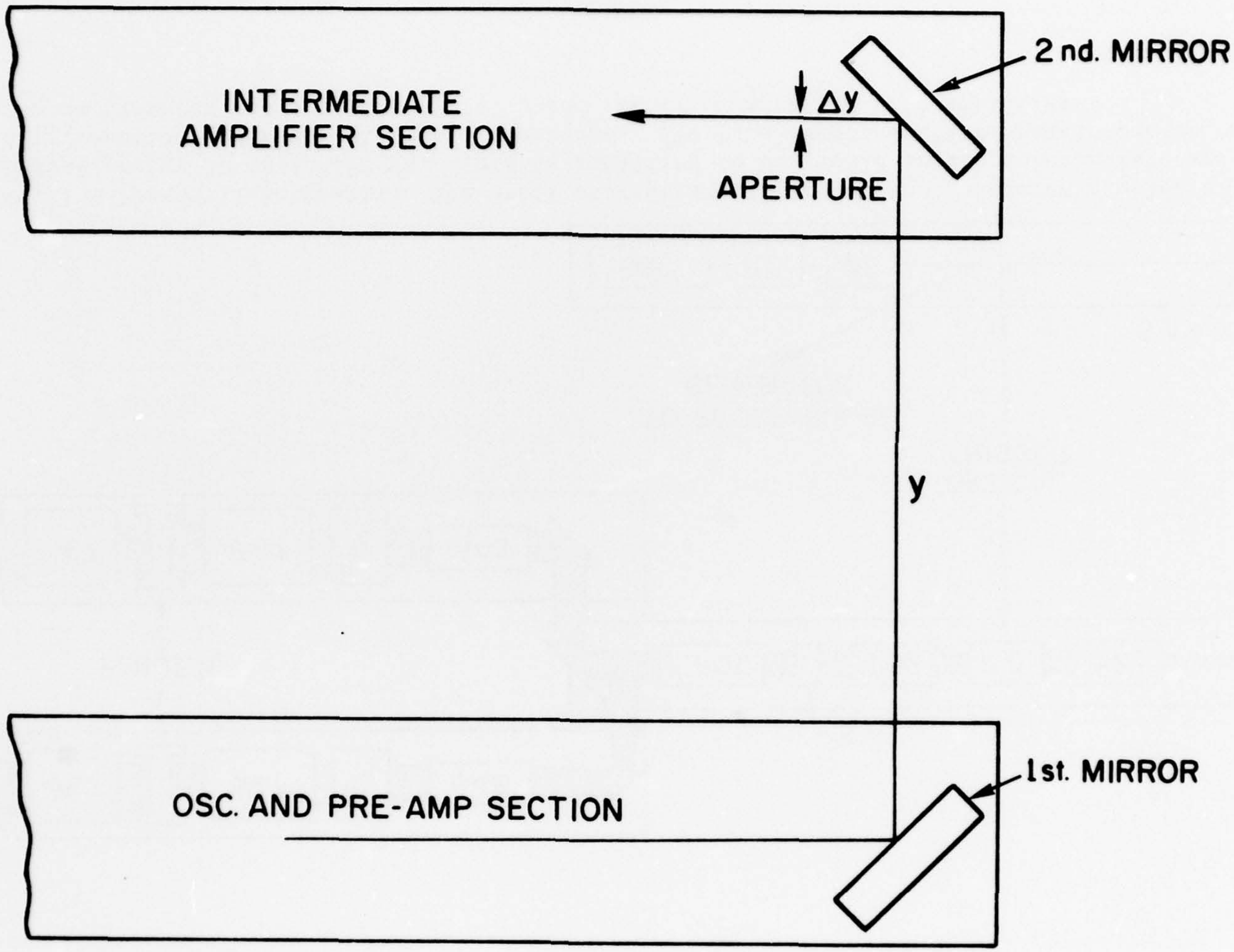

Fig. 2 - Detail of transfer mirrors between the oscillator and preamplifier section and the intermediate amplifier section.

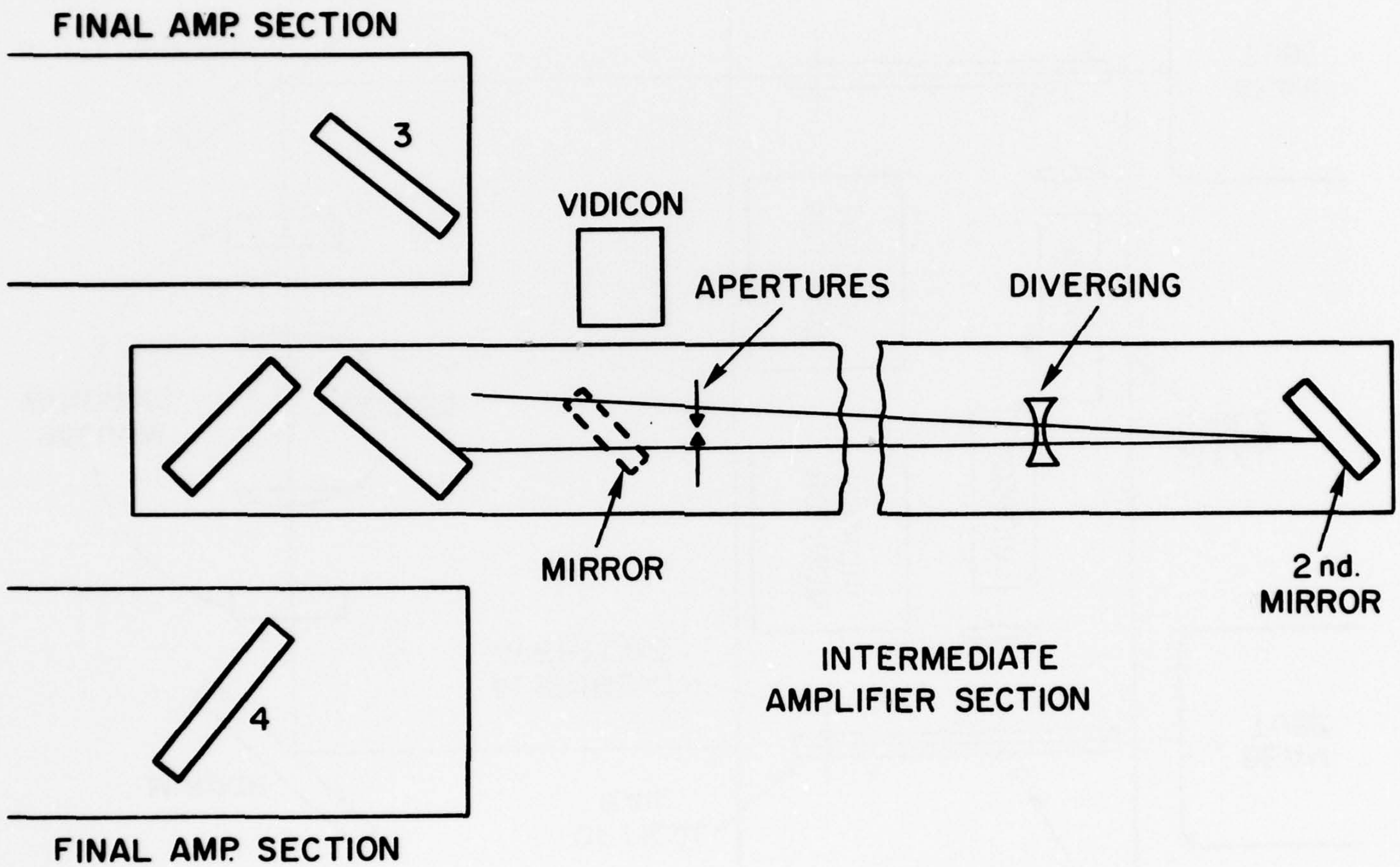

Fig. 3 - Detail of alignment components in the intermediate amplifier section.

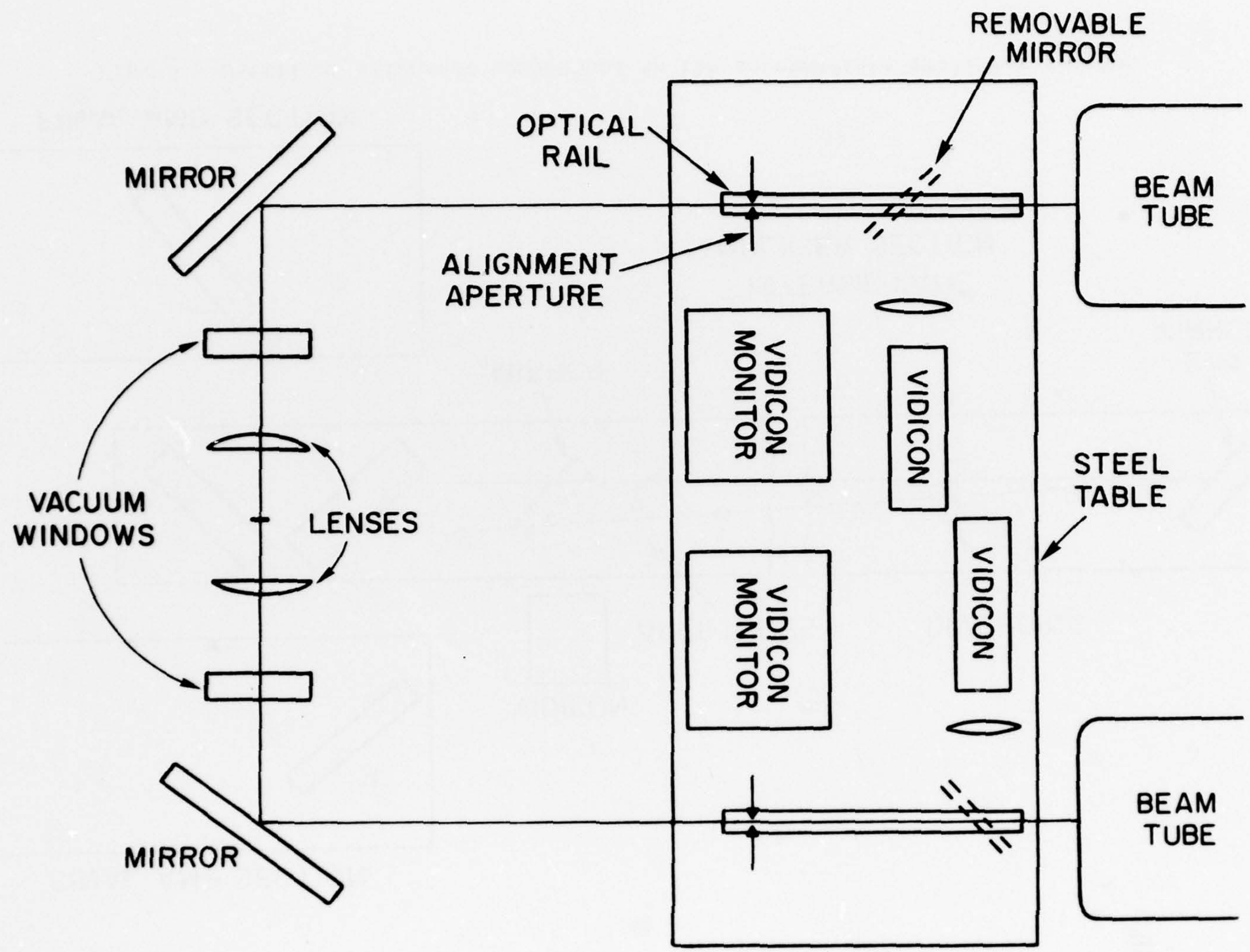

Fig. 4 - Detail of alignment components and sensors in the target area.

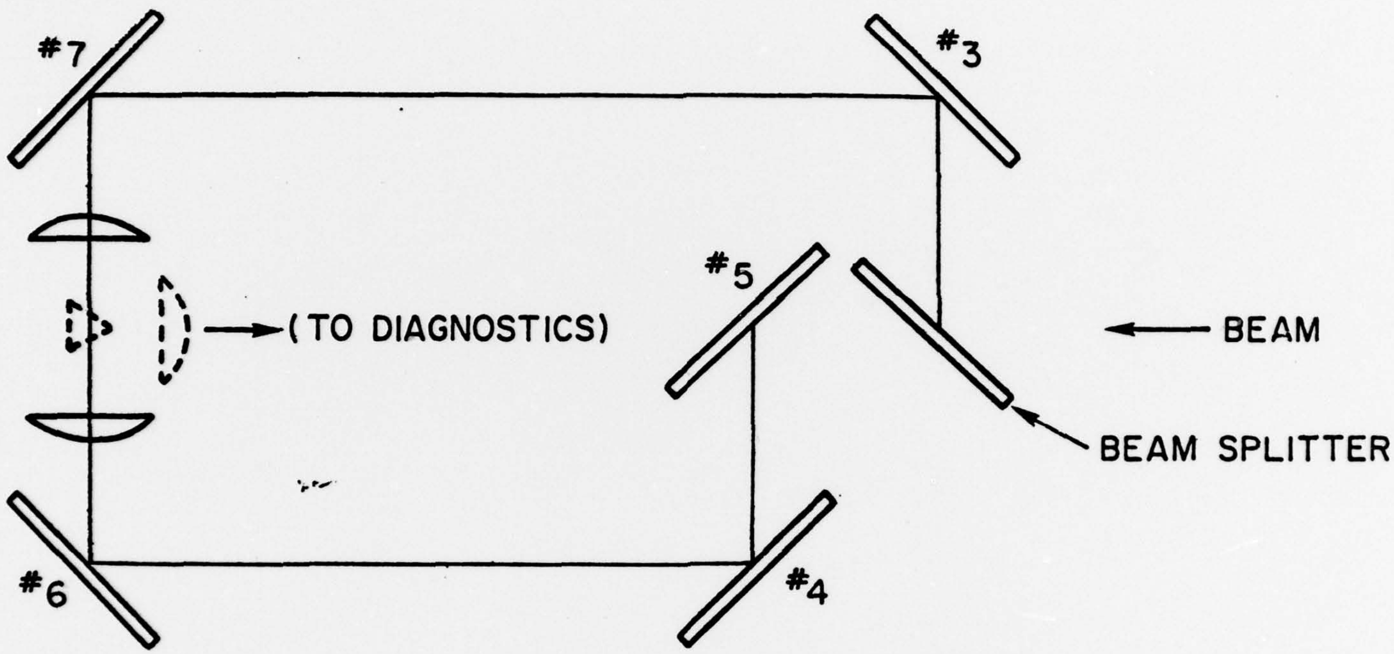

Fig. 5 - Optical schematic of system used for beam synchronization.